ISSN 0016-8521, Geotectonics, 2015, Vol. 49, No. 4, pp. 342–359. © Pleiades Publishing, Inc., 2015.

Ridge Push Engine of Plate Tectonics[1]

N. H. Swedan

Pacific Engineering, PLLC, 9350 Redmond Woodinville Road NE, Unit B210, Redmond, WA 98052, United States of America

e-mail: nabilswedan2@gmail.com

Received September 19, 2014

Abstract—Convection of the upper mantle drives the tectonic plates. This convection is a thermodynamic cycle that exchanges heat and mechanical work between mantle and tectonic plates. Thermodynamics and observations indicate that the energy of the geological activities resulting from plate tectonics is equal to the latent heat of melting, calculated at mantle's pressure, of the new ocean crust regenerated at midocean ridges. This energy varies with the temperature of ocean floor, which is correlated with surface temperature. The main objective of this manuscript is to demonstrate that plate tectonics is a thermodynamic engine and can be calculated as such. Unlike existing tectonic models, the thermodynamic model is very sensitive to variations of the temperature of ocean floor, which is correlated with surface temperature. Therefore, the observed increase of geological activities can be projected with surface temperature rise. Other objectives of the manuscript are to calculate the force that drives the tectonic plates, estimate the energy released, and validate the calculations based on experiments and observations. In addition to the scientific merit of projecting the geological activities, a good projection can have a broader impact at the societal and economical levels. Investment and insurance related decisions are affected by climate change, and our ability to project the geological activities is of paramount importance for the economy and public safety. This work can thus provide tools to assess the risks and hazards associated with the trend of geological activities with surface temperature rise.

Keywords: plate tectonics, force, energy, thermodynamics

DOI: 10.1134/S0016852115040081

INTRODUCTION

Mantle convection as a possible cause of the motion of the tectonic plates is mentioned in [20], who said that "thermal convection in some form is the only source of sufficient energy". Attempts to explain how the large-scale convection of the mantle actually drives the tectonic plates is an ongoing research subject. A partial list of related publications include [4, 5, 12, 24]. They suggest that the large-scale convection of the deep mantle drives the tectonic system. Other publications suggest that smaller-scale convection of the upper mantle contributes to the dynamics of plate tectonics. These include [11, 16, 21, 29]. A. Lenardic et al. [19] explore possible link between climate change, mantle convection, and tectonics. These cited papers reference a large number of publications that can be referred to for further reading on the subject of mantle convection.

Generally the available publications attempt to find a relationship between mantle convection and motion of the tectonic plates. Mantle plumes are thought to rise from the deep mantle and thermochemical plumes [17], interact with mantle free convection. The dynamics of mantle convection provides the drag forces of tectonics. Convection cells are generated that provide the energy and power required to drive the tectonic plates. The upper mantle convection is thought to be limited to the thermal boundary layer that occurs at the lithosphere–asthenosphere boundary and at the bottom of the upper mantle. This upper mantle convection is assumed to be made of many cells [21], that maintains an almost isothermal region below the lithosphere. In this scenario, the driving force is not associated with small-scale convection; it is assumed that buoyancy forces localized at ridges and ocean trenches maintain the motion of the tectonic plates. A.A. Kirdyashkin and A.G. Kirdyashkin [18] calculate the forces to which the plates are subjected in subduction zone as a result of mantle convection. Others use the isostasy principle and dynamic equilibrium to calculate the force and energy of plate tectonics. The calculated force and energy of tectonics using these methods do not vary significantly with the temperature of the ocean floor and they cannot be used for projecting the observed increase of geological activities with surface temperature rise. The temperature of the ocean floor is correlated with surface water temperature through the thermohaline circulation.

There appear to be no discussions in the literature suggesting that plate tectonics is a thermodynamic system driven by forced convection of the upper mantle. Nor are there publications that calculate the tectonic system by the traditional thermodynamic equations. E.G. Backus [3] suggested the possibility that the earth contains at least two heat engines and

[1] The article is published in the original.